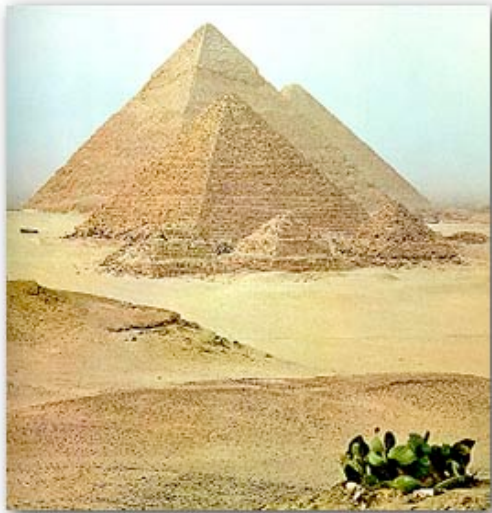


# Cosmic Ray Research Collaboration LOI Joe Wang

LBNL

- Research Focus:  
(1) Attenuation and Distribution of Muon Fluxes and Associated Spallation Products, for Background Measurements and Potential Development of Geophysical Tool to Detect Underground Openings



Khephren, Egypt; Luis Alvarez, UCB 1960's.



Pyramid of the Sun, Teotihuacan Mexico;  
Autoro Menchaca, Nat. Autonomus U. 2005

# **Structures Quantified and Influenced by Cosmic Ray (Muon) – Neutrino Detectors**

- Gran Sasso/MACRO - Italy
  - Shadow of the Moon
  - Overburden of Mountain Ranges
- SNO - Canada
  - Fault
  - Sand Filled Iron Ore Mining Region
- Homestake - DUSEL (TBD)
  - Multi-Level Drifts
  - Folded Ore Bodies

# Mapping of Cosmic Ray Flux at DUSEL - Geophysical Imaging Development

- Low Resolution ( $\sim 3^\circ$ ) Mobile Sensor along Drifts
- High Resolution ( $\sim 1^\circ$ ) Stations at Deep-Levels
- Calibrated with EM, Seismic Images
- 3D Density Structure Modeling instead of 1D Standard Rock (Constant Density) Interpretation



# Cosmic Ray Research Collaboration LOI (cont.

- Research Focus:  
(2) Dependence of Gene Mutation Rates on Radiation Levels

**Gran Sasso  
PULEX-2**

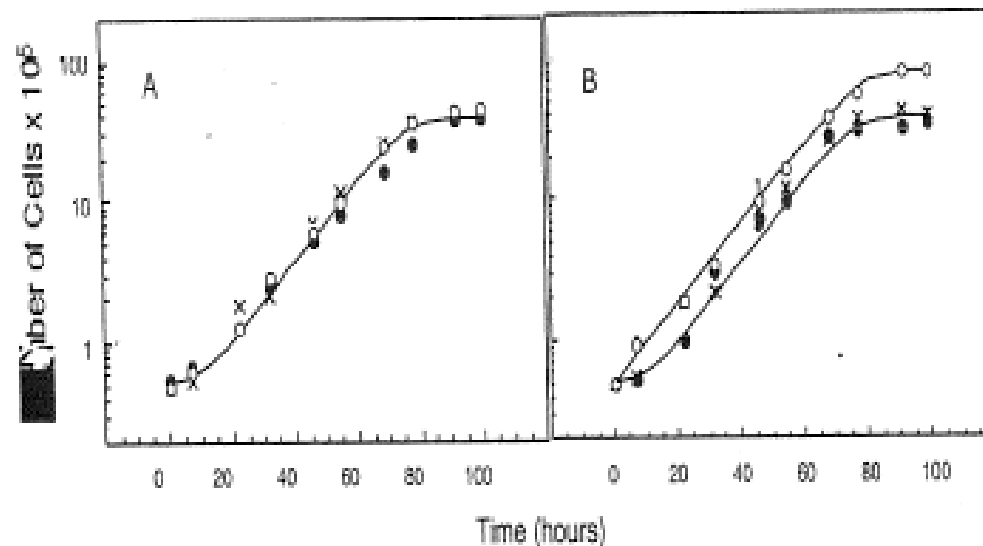


Figure 1: Growth rate of V79 cells cultured at the ISS (panel A) and at the LNGS (panel B). x: zero time; full circle: 3 months; open circle: 9 months.

- Common Interests with SDSU, BNL, SDSMT, ...
- Space Requirements: Extensive Access, Computation Centers, Assembly Facilities, Labs for



# **Biological Effects of Very Low Levels of Radiation**

## **Health Physics at the Homestake Mine**

by Dr. Robert J. McTaggart  
South Dakota State University

## **Endogenous Clustered Damages in Human Tissues & Cells**

by Dr. Betsy Sutherland  
Brookhaven National Laboratory

# Health Physics at the Homestake Mine

Homestake Mine Meeting

February 9-11, 2006

Dr. Robert J. McTaggart

Image Courtesy of South Dakota Art Museum, Brookings, SD 57007

# South Dakota State University

Dr. Robert J. McTaggart  
Assistant Professor of Physics

Dr. Thomas Cheesbrough, Chair  
Department of Biology



# BEIR VII Report<sup>1</sup>

- Biological Effects of Ionizing Radiation
- A **low dose** lies between 0 and 100 mSv (10 rem) or 100 mGy (10 rads) from X-rays, gamma rays, and neutrons.
- You receive ~ 0.350 rem per year (2/3 natural, 1/3 man-made).
- **How are the rates of diseases affected by low levels of radiation?**

<sup>1</sup> <http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2005/secy2005-0202/2005-0202scy.html>

# BEIR VII Data

- Several populations were studied, including workers in the nuclear industry, physicians, and survivors of Chernobyl.
- The most significant sample comes from the survivors of the Nagasaki and Hiroshima atomic bomb survivors (Radiation Effects Research Foundation or RERF).

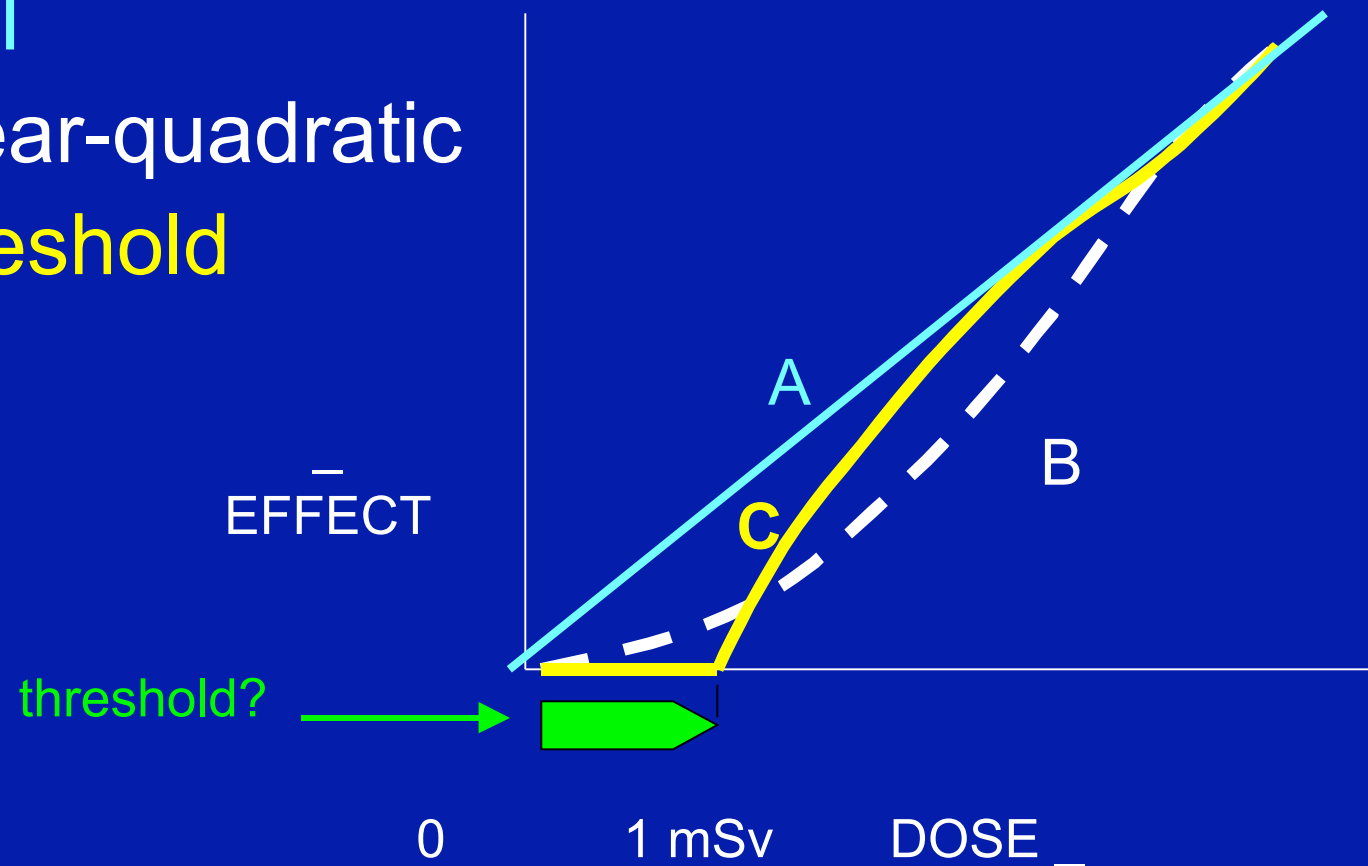
# BEIR VII Conclusions

- A linear relationship between the number of cancers and the radiation dose best describes the data.
- A threshold (i.e. no cancers produced for a given dose) could not be excluded for doses less than 0.1 Sv (10 rem).
- Genetic effects can be passed down in mice, but were not seen among successive generations of bomb survivors.

# LOW-DOSE RESPONSE CURVE?<sup>2</sup>

3 models:

- A = LNT
- B = linear-quadratic
- C = threshold





# Significance for Health Physics at Homestake

- “The Committee acknowledged that the mechanisms that lead to adverse health effects after ionizing radiation exposure are not fully understood.”<sup>2</sup>
- Below 20 mGy (2 rads), BEIR VII does not state whether the number of damaged DNA sites is linearly related to the dose received.

<sup>2</sup> <http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2005/secy2005-0202/2005-0202scy.html>

# Plan of Study

- We propose to study the biological effects of low levels of radiation on several different organisms.
- These experiments take advantage of **free** cosmic rays, the shielding provided by the rock, and the low Radon levels ( 1-5 pCi / L ).

# Biological Systems

- Bacteria and yeast
- Insects: *Drosophila* (fruit flies), Aphids
- Mammalian tissue samples

# What are we looking for?

- Point mutations in a known gene.
- A total count of mutations (harder to do).
- Morphological defects.
- Chromosomal translocation.
- Metabolic changes.
- Changes in rates of mutation and metabolism without radiation.

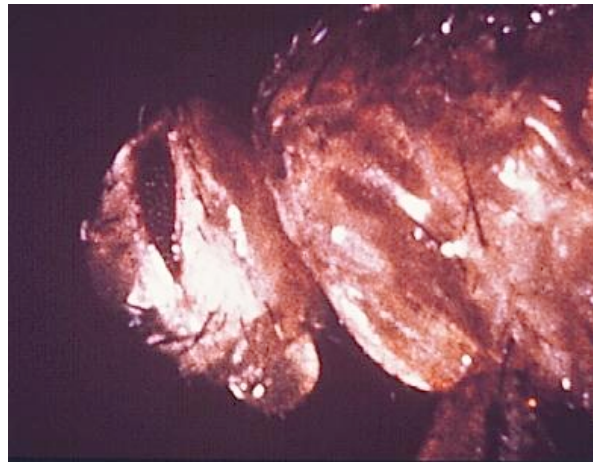
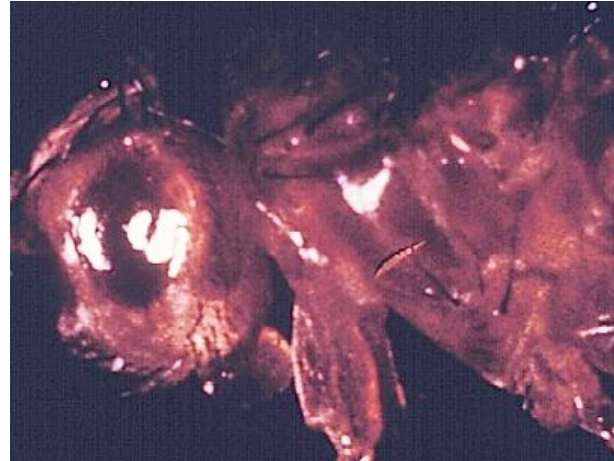
# The good....

- Bacteria and yeast are easy to use.
- Insects can have short life-cycles.
- Aphids can be cloned, yielding identical samples at all depths.
- Mammalian tissue samples would yield more relevant data for humans.
- Species with only 1 copy of a chromosome (haploids) are particularly sensitive.

# The bad....

- Bacteria can undergo horizontal gene transfer.
- Drosophila can be affected by P-element induced rearrangements.
- The entire genome is not completely known for many systems.
- Contamination is an issue, especially for mammalian tissue samples.

# The ugly.







# Requirements

- Storage similar to a typical office environment at several levels, although the surface and lowest levels would be preferable initially.
- Laminar flow hoods with HEPA filters.
- Sterility is a significant issue for mammalian tissue samples.
- Day/night cycles are important for insects.
- Environmental controls ( $\text{CO}_2$ ,  $\text{O}_2$ , temperature, etc.).

# Benefits

- Nearby cosmic ray assays would get a 2<sup>nd</sup> use.
- Genetic analysis can be farmed out relatively cheaply and yield a large statistical sample.
- We would interact with the North Central Agricultural Research Laboratory in Brookings (a.k.a. “The Bug Lab”).
- Bacteria and yeast experiments can enter the mine relatively quickly.

# In summary...

- We shed light on the basic interactions between DNA and ionizing radiation.
- We take advantage of the natural attributes of the mine.
- Funding needs to be developed.
- Several experiments can be deployed fairly soon.

# Endogenous Clustered Damages in Human Tissues & Cells

Betsy Sutherland  
Biology Department  
Brookhaven National Laboratory

[BMS@BNL.GOV](mailto:BMS@BNL.GOV)

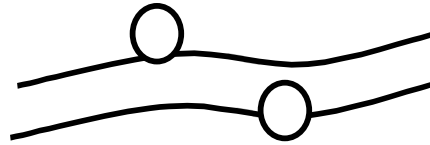
631 344-3380

# Bistranded Clustered Damages

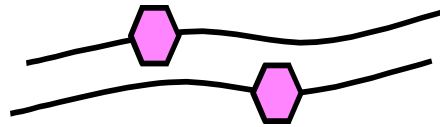
- Two or more lesions in 1-2 DNA helical turns

- May contain

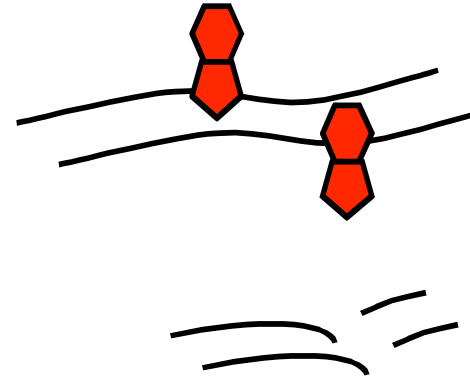
- abasic sites



- oxidized bases



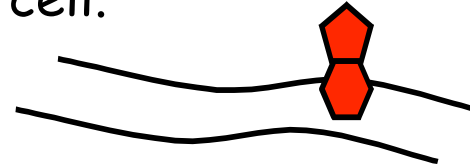
- strand breaks



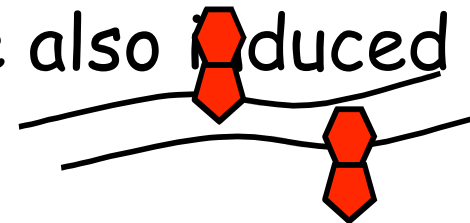
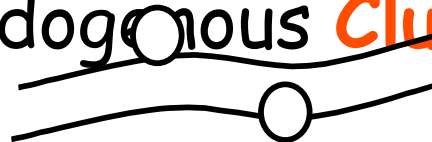
- Hard to repair, critical lethal & mutagenic damages

# Endogenous Clustered Damages in Human Tissues & Cells

- Isolated oxidized lesions are induced in cells.
  - ~ 10,000 oxidized lesions induced per cell per day.
  - Steady state levels of ~ 2000/cell.



- Endogenous **Clusters** are also induced in humans.





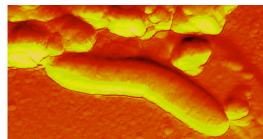
# DNA Damages Can Be Quantified in Simple & Complex Systems



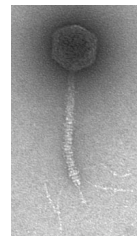
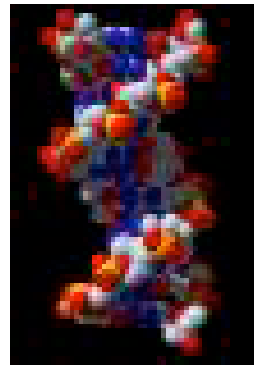
Human tissue



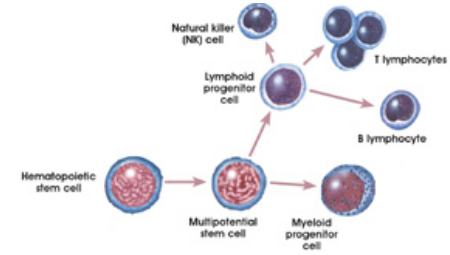
3D human tissue  
models



Microorganisms



Bacteriophage



Human hematopoietic  
stem & progenitor cells



Field samples



Higher plants

# Questions & Experiments

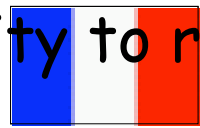
- Are "endogenous" damages induced by
  - Cellular oxidative metabolism (current assumption)
- Or
  - By background cosmic rays?
- We can test this current assumption by growing tissues & cells in lower background environments.

Companion experiments:

growth rates

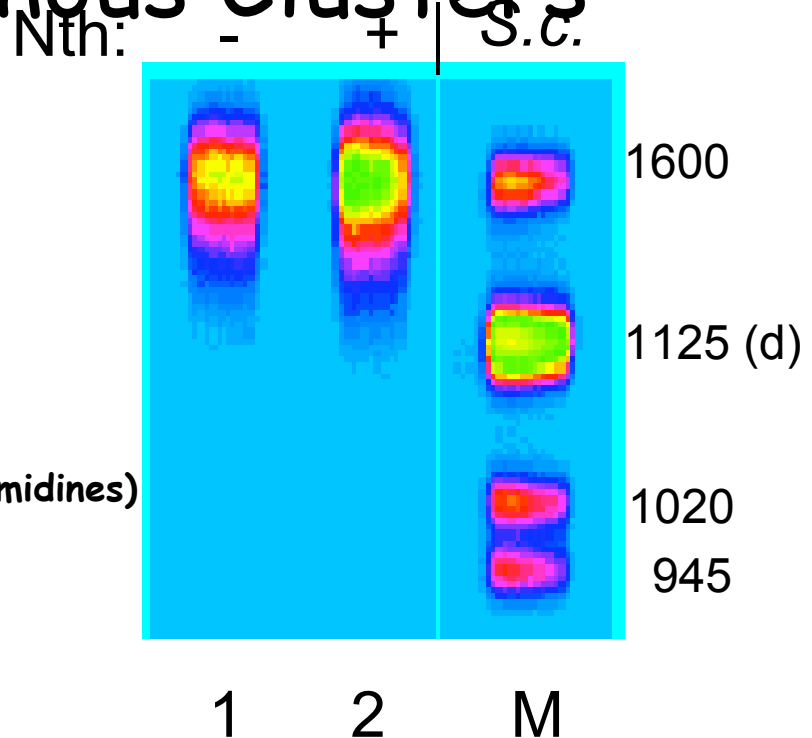
mutant frequencies

capacity to repair challenge radiation doses.



# Measuring Endogenous Clusters

- Unirradiated cells
- Isolate DNA in agarose
- NotI restrict
- +/- Nth protein (cuts at oxidized pyrimidines)
- Neutral pulsed field gel
- Stain with ethidium
- Quantitative electronic image
- Calculate number average length
- Calculate cluster frequency



DNA from Unirradiated Human cells  
Without (lane 1) Nth treatment  
With (lane 2) Nth treatment

Molecular length standards (lane 3)  
*S. cerevisiae* chromosomes